A METHOD TO ASSESS THE IMPLICATIONS OF FUTURE URBAN EXPANSION ON RURAL LAND

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A METHOD TO ASSESS THE IMPLICATIONS OF FUTURE URBAN EXPANSION ON RURAL LAND

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ABSTRACT

In Canada, as elsewhere, there has been an outward expansion of urban centres in order to accommodate the land demands for urban activities. A variety of resource conflicts have arisen as a result, one of the most actively discussed in recent times being the development for urban uses of land with high capability for renewable uses. While there have been numerous studies undertaken in an effort to estimate the extent and rate of conversions of rural land, especially agricultural land, to urban land uses, there has been much less attention devoted to estimating the extent and possible implications of future land conversions. In this report an approach to estimating future rural to urban land conversions is described and a method to assess the implications of land conversions in terms of the land resource for rural land use activities is developed. A pilot study, implemented to assess the implications of future land conversions for agriculture in Ontario, provides an illustration of the approaches described.

RÉSUMÉ

Au Canada comme ailleurs, les centres urbains ont connu une expansion considérable afin de répondre aux besoins fonciers des activités urbaines. Il en a résulté une grande variété de conflits dont l'un des plus fréquemment mentionnés ces dernières années concerne l'urbanisation de terres à forts potentiels pour des utilisations renouvelables. Un grand nombre d'études ont été entreprises en vue d'évaluer l'ampleur et le taux d'urbanisation de l'espace rural et principalement des terres agricoles, mais l'étendue et les conséquences possibles des futurs changements d'utilisation des terres n'ont pas fait l'objet d'une aussi grande attention. Ce rapport décrit une approche visant à évaluer la future urbanisation des terres rurales et une méthode d'évaluation de ses répercussions sur la ressource - terre nécessaire aux activités des terres rurales. Une étude pilote mise en oeuvre pour évaluer les répercussions des futurs changements d'utilisation des terres sur l'agriculture en Ontario sert d'exemple d'application des méthodes décrites.

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1. INTRODUCTION

Land is a finite resource and must be allocated amongst competing land use activities. In particular, the areas surrounding urban centres are characterised by a competition between various rural land use activities and outward spreading urban land uses. This competition has aroused consi derable concern in Canada in recent times, centering especially on the conversion of agricultural land to urban land uses.

Although the nation has a total area of approximately 1 billion hectares, only 11 percent of this is capable of supporting any type of agricultural use (Manning and McCuaig, 1977). Moreover, 55 percent of Canada's total high capability agricultural land (Canada Land Inventory classes 1-3) is located within a 161 kilometre radius of the 23 largest urban centres (Neimanis, 1979). Not only is the land in close proximity to urban centres rated highly for agriculture in terms of soil characteristics, but it is also rated highly for agriculture from a climatic standpoint. The best 5 percent of Canadian farmland rated agroclimatically is located in Census Divisions containing 50 percent of the urban population (Williams, Pocock and Russwurm, 1978).

It is not surprising, therefore, that in recent land conversion studies it has been calculated that approximately 60 percent of all rural land converted directly to urban uses in Canada is in Canada Land Inventory agricultural capability classes 1-3 and that more than 50 percent of rural land converted to urban land uses had previously been devoted to improved agriculture (Gierman, 1977; Warren and Rump, 1981).

The reaction to findings such as these has been mixed. Many people have expressed alarm and strongly advocated the preservation of the agricultural land resource (Crerar, 1962; Pearson, 1974; Krueger, 1978; MacGregor, 1980; Toronto Star, 1981). It has also been suggested that while the conversion of agricultural land to urban uses warrants attention, the extent, rate and implications of such conversions are less significant than suggested elsewhere (Centre for Resources Development, 1972; Gray, 1974, 1976; Frankena and Scheffman, 1980).

To date, response to this land issue has varied markedly across the country. The most notable legislative examples are the British Columbia Land Commission Act (Baxter, 1974) and Bill 90 in Quebec, Loi sur la protection du territoire agricole (Troughton, 1981). In Ontario the response has been moderate. The Food Land Guidelines were released in 1978 in an effort to assist local municipalities, counties and regions in planning for agriculture (Government of Ontario, 1978) but compliance is largely voluntary. At the federal government level, an Interdepartmental Task Force on Land Use Policy (Environment Canada, 1980) has recommended the review of federal programming as it influences the use of high capability land, and these recommendations have been adopted by Cabinet as part of the Federal Policy on Land Use (Government of Canada, 1981).

There is clearly a need to carefully establish the necessity for further regulation of land use changes with respect to the allocation of land to urban and agricultural uses, as well as other rural land uses. Whilst information on past trends

has some value in this regard, reliable estimates of future land conversions and some assessment of the implications of these conversions for rural land uses would greatly assist in defining the need for land use policy.

This report describes a method for estimating the extent of future rural to urban land conversions and for assessing implications of these conversions, not only for agriculture, but for all rural land uses. The methodology is demonstrated by a pilot study for Ontario, in which future land conversions are estimated and implications for agriculture are assessed.

This province is selected for the pilot study since in the periods 1966-1971 and 1971-1976 it accounted for over 40 percent of the total national land conversion acreage (Gierman, 1977: Warren and Rump, 1981). Also, because of the large number of urban centres within this province, representing the entire range of city sizes in Canada, it offers a good opportunity to extensively evaluate the methods employed. Furthermore, Ontario incorporates approximately 50 percent of the highest capability agricultural land (CLI class 1) in Canada.

It must be emphasised at the outset that the method is developed to estimate future direct urban expansion: that is, the accretionary extension of existing urban centres. This study does not estimate the conversion of rural land to indirect urban land uses, such as rural residential development, hobby farms, and golf courses. In addition, estimates of the extent of induced impacts, for example caused by urban infrastructure expansion, are not included.

2. RURAL TO URBAN LAND CONVERSION - A REVIEW

The conversion of rural land to urban land uses did not become a matter of widespread concern until the period of rapid urbanisation in Canada following World War 2. The results of early studies were consolidated at the 1961 'Resources for Tommorow Conference' at which it was predicted that as a result of urban expansion there would be 'no significant agricultural production' by the year 2000 in three of Canada's major farming regions; the lower Fraser Valley of British Columbia, and substantial areas of the St. Lawrence lowlands and southern Ontario (Crerar, 1962).

An important outcome of this conference was the recommendation for an inventory of land resources for use in national, regional and local land use planning. This supported the recommendation made by the Special Senate Committee on Land Use in 1958, that a comprehensive survey of the capability and use of Canada's land resources be undertaken to facilitate improved land use planning. In 1963, the Canada Land Inventory (CLI) was established to classify lands according to use and their capability to sustain various land uses, a program that is now near completion. This, and the more recently established Canada Geographic Information System (CGIS), provide a useful information base for land use studies in Canada.

Studies have also been undertaken to estimate the extent and rate of rural to urban land conversions in Canada. Gierman and Lenning (1980) classify these on the basis of the orientation of the research. Urban-oriented research, the authors suggest, has been primarily concerned with the growth of

urban centres and the uses to which the land consumed is devoted (Ontario Department of Municipal Affairs, 1969, Bourne, 1976, Ravenau et al., 1973, Service d'Urbanism, 1969). The second type of research identified by Gierman and Lenning adopts a rural-orientation and examines the conversion of agricultural land to urban land uses. Studies of this type might be further dissected according to the form of urban expansion being considered. For example, some researchers have been concerned with the accretionary growth of urban centres as well as indirect urban expansion in the form of rural-residential development (Crerar, 1962, Hind-Smith and Gertler, 1962, Russwurm, 1970) Others have dealt only with direct urban expansion (Centre for Resources Development, 1972, Gray, 1974, 1976), whilst others have examined only indirect urban expansion, especially rural-residential development (Rodd, 1976a, Michie and Found, 1976, Punter, 1974, Martin, 1975).

Within this body of literature three major deficiencies exist. The first is that the analyses concentrate on the conversion of agricultural land to urban land uses and do not document the conversion to urban uses of rural land devoted to uses other than agriculture. Secondly, these studies typically deal with small regions and a limited number of urban places. Information on land conversions at a broader spatial scale is not readily available, and comparison of individual studies is difficult due to differing data bases, definitions, and time periods.

These two limitations have recently been overcome to a large extent as a result of rural to urban land conversion studies undertaken by the Lands Directorate of Environment Canada (Gierman, 1977, Warren and Rump, 1981). These have examined the conversion to urban uses of all types of rural land classified according to both use and capability to support various rural land use activities. The studies are national in coverage and deal with all urban centres whose census populations were 25,000 or more.

The third deficiency in this field of land use study is the lack of reliable estimates of future rural to urban land conversions. Typically, existing estimates are based on very general assumptions regarding conversion rates and are for an aggregate of urban places (Nowland, 1975, McKeague, 1975, Yeates, 1975). Estimates at the level of the individual urban centre provide greater opportunity to assess the implications of future conversions, but examples of these in Canada are very rare (Centre for Resources Development, 1972). This study presents a methodology for deriving such estimates and for assessing implictions of such conversions for rural land uses. Additionally, to illustrate the methodology a range of estimates of rural to urban land conversions are provided for Ontario, and likely impacts of these on the agricultural land resource in that province are assessed.

3. ESTIMATING FUTURE RURAL TO URBAN LAND CONVERSIONS

The analysis can be divided into two distinct components. The first of these is the calculation of estimates of the extent of future rural to urban land conversions. The second is the assessment of implications of the estimated land conversions for rural land uses. In this section several methods for deriving land conversion estimates are considered. Each approach is described, the

major assumptions are identified, and potential applications of the method are evaluated. The methods reviewed here represent the major approaches that have been adopted in previous studies of rural to urban land conversion.

3.1 Simple Extrapolation

One approach to estimating future rural to urban land conversions is to extrapolate calculated annual land conversion rates for a previous time period over the future time period under consideration for each urban centre. This assumes, of course, that the annual conversion rate calculated for the previous time period will remain constant over the future time period.

Although appealing in its simplicity, available data indicate that annual rates of land conversion vary greatly over time. For Canada, the average annual rate of land conversion for the period 1966-1971 was 17,219 hectares, compared with an average of 12,460 hectares per year for the 1971-1976 period (Gierman, 1977; Warren and Rump, 1981). These same land conversion studies document similar variations in provincial and individual urban centre conversion rates over the same two periods. If data were available for a sufficient number of time periods, though, it may be possible to extrapolate a trend for previous time periods over the future time period.

An alternative to extrapolating annual conversion rates is to extrapolate either change in total urban area, or total urban area, for individual urban centres over the future time period. This assumes that observed trends in urban expansion will continue over the future time period.

To confidently estimate future land conversions by this method requires time series data for each centre. Currently such data are not readily available (Gad, 1973). Furthermore, the extrapolation method does not permit analyses to be conducted under alternative assumptions of population change and/or density of development. Recent evidence indicates that neither rates of population change (Bourne and Simmons, 1979), nor past densities of population growth (Gad, 1973, Warren and Rump, 1981) have been constant over previous time periods, and nor are they likely to remain constant over future time periods.

3.2 Probability Methods Applied to the Urban System

Change in urban area, which implies a change in rural land area, can be described using probalility matrices. Bourne and Gad (1972) examine changes in the Ontario and Quebec urban systems by grouping cities according to size and calculating the probabilities of urban centres moving from one size category to another over census time periods.

The analysis was undertaken for two different time periods, 1941-1951 and 1951-1961, and the authors make several important observations in comparing the results. Firstly, the probabilities of urban centres moving from one size category to another are generally low (most are less than 0.40) and in many cases the probabilities are zero. No urban centres shift more than one size category over a time period. Secondly, the probabilities calculated for the period 1941-1951 differ markedly from those calculated for the 1951-1961 period. Bourne and Gad attribute this to a limited sample size and infrequent movements of urban centres from one size category to another. Also contributing to this insta-

bility between time periods is a clustering of centres of similar size in terms of positional changes in the probability matrices. Finally, the results of the analysis are found to be sensitive to the number and size of the urban hierarchy categories and to spatial boundary definitions of the urban centres. The authors conclude, however, that deriving a sequence of probability matrices for several census periods would provide an excellent basis for the extrapolation of the growth of an urban system without having to identify each of the contributing factors to the growth process.

In this research, the effects of limited sample size might also be experienced and the sensitivity of the analysis to definitions of the urban size categories suggests problems in selecting appropriate size classes. Of more significance, though, is the requirement to place urban centres into size categories. Using this method, patterns of growth in urban areas refer to groups of centres, and provide a poor basis for predicting future land needs of particular centres.

3.3 Regression Methods

An alternative approach to estimating future urban land requirements is to use bi-variate regression analysis. High correlations have been found between the logarithm of urban population and the logarithm of urban area and this relationship has been expressed in a regression framework for a variety of purposes (Boyce, 1963, Ontario Department of Municipal Affairs, 1969, Best et al., 1974). The relationship in its most general form can be expressed as:

$$A = f(P) \qquad (1)$$

That is, urban area (A) is a function of urban population (P).

When the two variables, urban area and urban population, are transformed logarithmically the relationship is linear and can be expressed algebraically as:

$$\text{Log}A_{i1} = a + b.\text{Log}P_{i1} + e_i \qquad (2)$$

where A_{i1} is the area of urban centre i at time t=1,

P_{i1} is the population of urban centre i at time t=1,

a and b are regression coefficients, and

e_i is an error term.

Estimates of future urban area can be calculated by substituting population projections for individual urban centres into the regression equation, once the coefficients are known:

$$\text{Log}\hat{A}_{i2} = a + b.\text{Log}\hat{P}_{i2} \qquad (3)$$

Where $\hat{A}_{i2}$ is an estimate of the area of urban centre i at time t=2, and

$\hat{P}_{i2}$ is a population projection for urban centre i at time t=2.

To estimate future land conversions, the area of an urban centre in the base year can simply be subtracted from its predicted future area:

$$\Delta\hat{A}_{i1\,2} = \hat{A}_{i2} - A_{i1} \qquad (4)$$

It is assumed in this estimating procedure that the relationship between population and area at the initial time point will prevail at the future time point. With the present period of slow economic growth, rising

energy prices and high housing costs, it is likely that changes in urban development patterns, such as renovation and infilling within urban centres will occur. Under such circumstances, the relationship between population and area will change. Thus, if a regression approach was adopted, it would be appropriate to investiage the stability of the regression coefficients over time and the consequent effects on the urban expansion estimates.

It is also assumed that the regression coefficients, which express the relationship between the logarithm of urban area and the logarithm of urban population over all of the urban centres, express the relationship between the logarithm of urban population and the logarithm of urban area for each of the urban centres. However, individual urban centres deviate from this 'average' relationship (Boyce, 1963), and these deviations are typically referred to as residuals.

Unsatisfactory predictions of future urban expansion may result from this estimation method. This can be illustrated by considering an urban centre that has a large positive residual; that is, the centre covers a larger area than that assumed in equation (1). Using the estimating procedure described above (equation 2), an increase in the population of the urban centre could result in an estimated future urban area smaller than the area occupied by that centre in the base year. This is illustrated in Figure 1, where the area of urban centre c is predicted to decrease from A_1 to A_2.

When estimating the future land requirements for 18 urban centres in southern Ontario on the basis of a log-area--log-population regression equation (Centre for Resources Development, 1972), this problem was circumvented by using the regression equation to predict the developed area at time t=1, in this instance being 1971. Total developed area for several future time points was then predicted using the same regression equation and future changes in urban area were measured using the predicted 1971 area as the base.

An alternative modification is to retain the residual, or error term, in the estimating equation:

$$\text{Log}\hat{A}_{i2} = a + b.\text{Log}\hat{P}_{i2} + e_i \qquad (5)$$

This modification to the estimating procedure is illustrated in Figure 2. The assumption here is that not only will the regression coefficients be constant over time, but also that the residual calculated in equation (1) is constant over time.

Future urban land requirements might also be predicted on the basis of the relationship of urban area to more than one other variable, using a multiple regression equation. Variables that might be included in a multi-variate predictive equation could relate to economic, demographic, social, and locational characteristics of an urban centre (Golant, 1972).

The procedure and assumptions of a multiple regression approach are similar to those of a bi-variate regression model, although additional assumptions, such as statistical independence among the independant variables, must be satisfied to ensure the reliability of the model (Taylor, 1977). Further difficulties may be encountered since, even when some of the independant variables may be logged the future values of other independant variables

FIGURE 1 AREA ESTIMATION USING REGRESSION COEFFICIENTS

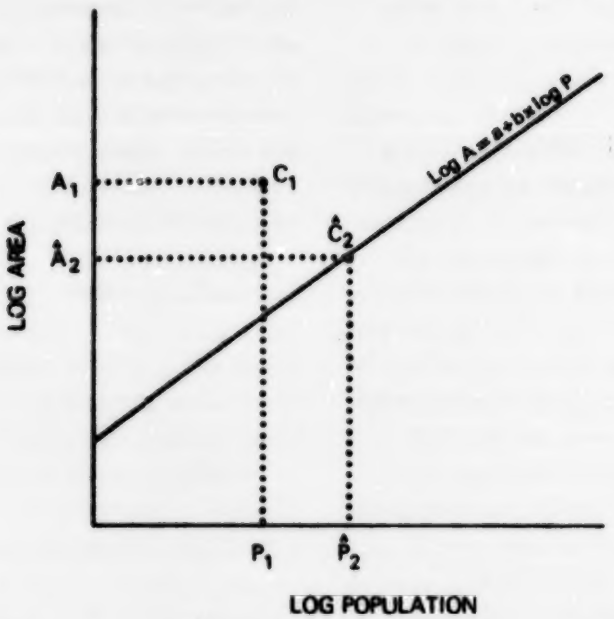
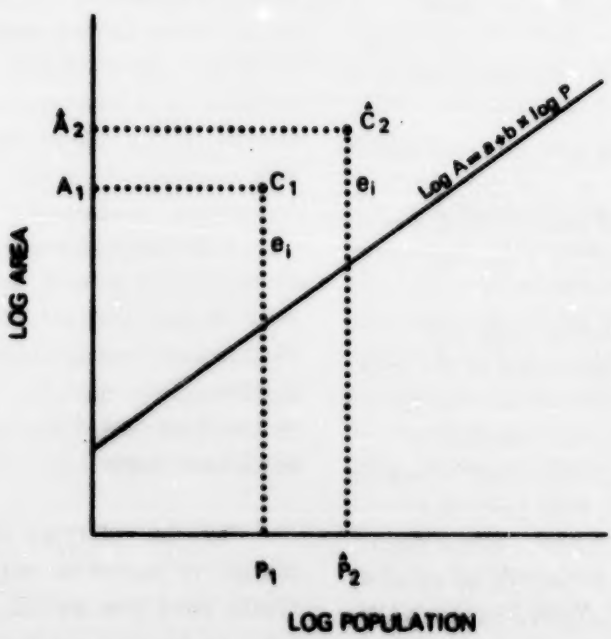


FIGURE 2 AREA ESTIMATION USING REGRESSION COEFFICIENTS AND ERROR TERM



must be predicted. However, estimates of their future values may be as difficult, or more difficult, to predict than the future urban land requirements themselves.

3.4 Ratio Methods

The ratio methods of estimating future land conversions are based on the relationship between area and population for urban centres and have the advantage over regression and probability methods in that they allow for differences in growth characteristics for individual centres. The most recent changes in urban area relative to changes in urban population can be measured using the Marginal Land-Population Ratio (MLPR), defined as the ratio of change in urban population over the same time period:

$$MLPR_{i1-2} = \frac{A_{i2} - A_{i1}}{P_{i2} - P_{i1}} \qquad (6)$$

where $MLPR_{i1-2}$ is the Marginal Land-Population Ratio for urban centre i for the time period t=1 to t=2,

A_{i2} is the area of urban centre i at time t=2, and

P_{i2} is the population of urban centre i at time t=2.

In Canada several studies have used a similar ratio to relate decreases in the area of farmland to changes in urban population; that is, the numerator in the equation is change in farmland area, rather than change in urban area (Crerar, 1962; Hind-Smith and Gertler, 1962; Russwurm, 1970). While these studies provide useful information on rates of change in farmland area relative to changes in urban population over previous time periods, these ratios are not appropriate for estimating future changes in farmland area, since the value of the ratio is dependent upon the distribution of agricultural land in the path of urban expansion. Furthermore, here the concern is with total future rural-urban land use change, which can be more effectively estimated by substituting MLPRs calculated using equation (5) into the following equation:

$$\Delta\hat{A}_{i2-3} = MLPR_{i1-2} \cdot \Delta\hat{P}_{i2-3} \qquad (7)$$

where $\Delta\hat{A}_{i2-3}$ is the change in area of urban centre i from time t=2 to time t=3, and

$\Delta\hat{P}_{i2-3}$ is the projected change in population of urban centre i from time t=2 to time t=3.

This approach is based on the assumption that the marginal ratio between t=1 and t=2 also applies between t=2 and t=3 for a given urban centre. A number of studies, though, have indicated that the ratio varies over time (Gad, 1973). If data were available for a sufficient number of time periods, it may be possible to extrapolate trends in the ratio and use an estimate of the future value of the MLPR.

A general problem associated with the use of the MLPR to predict future urban land needs is that the ratio may be subject to wide fluctuations from one time period relative to another. The reason for this is instability in the relationship between area change and population change.

This type of ratio is typically based on changes in population and area over a relatively short time period, usually less than 20 years (Neidercorn and Hearle, 1963; Hind-Smith

and Gertler, 1962; Gierman, 1977). If from one time period to another there is a significant difference in the rate of change in either population or area, that is not accompanied by a similar proportional change in the other, then the value of the ratio will differ markedly between the two time periods.

Fluctuations in rates of population growth are not uncommon. Bourne and Simmons (1979) note that the industrial and commercial centres of southern Ontario exhibit such fluctuations in concert with changing patterns of of economic growth. Even more susceptible to wide fluctuations in population growth rates, the authors note, are small resource based towns. If such fluctuations span two time periods and are not accompanied by similar proportional changes in areal growth rates, then the value of the ratio will differ from one time period relative to the other. Furthermore, it is possible that population may decline over a time period, especially in smaller urban centres with unstable economies. This will yield a negative MLPR, which implies from equation (6) that future increases in population will result in declines in urban area. Whilst rates of areal growth may also vary, perhaps in response to fluctuations in the housing market and investment conditions, it is very unlikely that a decrease in urban area would occur.

An alternative ratio on which estimates of future land conversions may be based is the Land-Population Ratio (LPR) which is the ratio of total urban area to total urban population:

$$LPR_{i1} = \frac{A_{i1}}{P_{i1}} \qquad (8)$$

where LPR_{i1} is the Land-Population Ratio for urban centre i at time t=1.

By substituting this ratio into the following equation, estimates of future land use change are derived:

$$\Delta\hat{A}_{i1\text{-}2} = LPR_{i1} \cdot \Delta\hat{P}_{i1\text{-}2} \qquad (9)$$

It is assumed that the LPR at time t=1 will also apply at time t=2 for each urban centre. As with the MLPRs, though, LPRs may be extrapolated over time and an estimate of the ratio used in equation (8).

The Land-Population Ratio is selected as the basis for estimating future rural to urban land conversions in the Ontario pilot study. Because extensive time series data are not available (see following section), it is considered that there is insufficient base for the use of simple extrapolation.

The LPR estimating procedure has the advantage over both regression methods and probability methods in that it incorporates growth characteristics of individual urban centres.

The Marginal Land-Population Ratio is a measure of development densities at the peripheries of urban centres where rural to urban land conversions are actually occurring. Thus, the MLPR will more clearly reflect recent changes in development densities in response to changing economic conditions, such as perhaps increasing densities of development due to rising energy prices and costs of housing. However, there are obvious risks in using the MLPR to estimate land conversions given the instability of short term relationships between urban area and urban population, as

reflected in the considerable variability of the MLPR over time (Gad, 1973; Smit and Cocklin, 1981a).

The LPR can be expected to be more stable over time than the MLPR since the ratio of totals and not increments is being used. In effect, the LPR at a point in time is an expression of the history of short-run (marginal) changes up until that time.

To estimate future land conversions using the LPR and, in fact, the MLPR and regression methods, requires data on independent variables. Obviously, the reliability of the data on the independent variable strongly influences the accuracy of the land conversion estimates. In the following section data requirements to calculate LPRs are discussed and a method to derive population projections, the independent variable in the LPR estimating procedure (see equation 9), is described.

3.5 Data Requirements

To employ the LPR for estimating future land conversions, data are required on total area and total urban population for individual urban centres. Four major sources of land use information (repeated ground surveys, census surveys, assessment rolls, and air photographs), from which urban area might be obtained, have been reviewed extensively elsewhere (Gad, 1973; Gierman and Lenning, 1980; Smit and Cocklin, 1981a). These authors conclude that air photographs, although subject to some interpretive problems, are an excellent source of land use information and can be used for time series analysis. The Lands Directorate of Environment Canada has recently undertaken two studies of rural to urban land conversion (Gierman, 1977; Warren and Rump, 1981) in which the urban area of individual urban centres was established from air photographs. Corresponding population figures for these centres were derived from the census. Urban area and urban population data are available for each of the years 1966, 1971 and 1976 from these studies. These two studies provide, at a national scale, the most comprehensive and reliable estimates of urban areas and urban populations, at the level of the individual urban centre and are, therefore, selected as the base for the calcualtion of LPRs in the Ontario pilot study.

The LPR-based projections also require estimates of change in population over the future time period. Although projections for individual urban centres are available from several sources (eg., Department of Treasury and Economics, 1970, Bourne et al., 1974; Wong, 1976), none of these encompass the entire set of urban centres that would be included in a national level study.

For the Ontario study, four projections for each urban centre are based on provincial level projections from Statistics Canada (1978). Since projections are required for individual centres, a relationship between the population growth of each urban centre and the population growth of the province was required. In this regard, two different assumptions were made:

1. The populations of all urban centres will increase at the same rate projected for the province:

$$\hat{P}_{12} = P_{11} \cdot \frac{\hat{P}_{02}}{P_{01}} \qquad (10)$$

where P_{01} is the population of Ontario at time t=1, and
$\hat{P}_{02}$ is the projected population of Ontario at time t=2.

2. The population growth rate of an urban centre over the future time period reflects the deviation in its recent growth rate from the provincial rate of population growth. This is based on the following relationship:

$$RI_{i\,1\text{-}2} = \frac{P_{i2}}{P_{i1}} \Big/ \frac{P_{02}}{P_{01}} \qquad (11)$$

where $RI_{i\,1\text{-}2}$ is the Relative Population Increase ratio for urban centre i for the period t=1 to t=2, and
P_{02} is the population of Ontario at time t=2.

When the RI takes a value of 1.0, the population of the urban centre changed by the same proportion as the population of the province over the previous time period. If the RI is larger than 1.0 the population of the urban centre changed by a greater proportion than that of the province; a value less than 1.0 indicates a lesser proportional growth in the population of the urban centre than for the province.

Population projections for each centre are derived by incorporating the RIs in the following equation:

$$\hat{P}_{i3} = \left(P_{i2} \cdot \frac{\hat{P}_{03}}{P_{02}}\right) \cdot RI_{i\,1\text{-}2} \qquad (12)$$

where $\hat{P}_{i3}$ is the population projection for urban centre i at time t=3, and
$\hat{P}_{03}$ is the projected population of Ontario at time t=3.

It is assumed that the ratio of the proportional change in the population of an urban centre to the proportional change in the population of the province is repeated for the future time period. Thus, the ratio approach, incorporates population growth trends for individual urban centres relative to provincial population growth trends for a recent time period. It is assumed that the RIs will not change over the future time period. Isard (1963) suggests that in more refined forms of the technique, past trends in the ratio are extrapolated over the future time period under consideration. Since population data are available for two five year time periods only (1966-1971 and 1971-1976), it is considered that there is not an adequate base for extrapolation and the RIs calculated for the ten year period, 1966-1976, are used.

It should be emphasized that the sets of assumptions employed here in estimating future populations of the urban centres represent only two of several that might be used. Recent research has indicated, for instance, that population growth rates of urban centres in the 30,000 to 100,000 population range have shown a marked increase, while growth rates in larger urban centres have fallen in recent years (Robinson, 1981). These results may provide justification for adjustments to be made in the assumed growth rates for individual centres - those for the largest centres being adjusted downward and those for smaller centres could be adjusted upward. If reasonable justification could be provided for the

Table 1

URBAN AREA-POPULATION RELATIONSHIPS FOR ONTARIO
URBAN CENTRES, 1976

Urban Centre	Urban Area 1976 (ha)	Population 1976	LPR
Barrie	3,624	36,326	0.100
Belleville	2,052	35,311	0.058
Brantford	5,104	75,718	0.067
Brockville	1,592	21,233	0.075
Chatham	2,166	38,685	0.056
Cornwall	2,299	46,121	0.050
Fort Erie	3,550	24,031	0.148
Guelph	3,529	67,538	0.052
Halton Hills	1,564	34,477	0.045
Hamilton	18,509	499,784	0.037
Kingston	5,952	78,623	0.076
Kitchener	11,897	259,270	0.046
London	10,973	247,263	0.044
Midland	2,398	20,625	0.116
North Bay	4,060	52,707	0.077
Oshawa	8,310	135,196	0.062
Ottawa	27,056	478,519	0.057
Peterborough	5,114	63,219	0.081
Sarnia	6,171	71,135	0.087
St. Catharines-Niagara	19,529	295,860	0.066
St. Thomas	2,447	28,913	0.085
Sault Ste. Marie	5,534	81,049	0.068
Stratford	1,731	25,657	0.068
Sudbury	10,126	156,840	0.065
Thunder Bay	7,222	111,476	0.065
Timmins	1,790	44,747	0.040
Toronto	91,665	2,778,720	0.033
Trenton	2,201	24,885	0.089
Windsor	13,216	223,922	0.059
Woodstock	3,166	26,779	0.118

magnitude of such adjustments, or for the adoption of other assumptions, alternative population projections might be incorporated.

3.6 Future Land Conversions in Ontario, 1976-2001

LPRs were calculated for each of the 30 urban centres in Ontario that were included in the Lands Directorate land conversion studies, using the 1976 urban area and urban population data (Table 1). Alternative approaches might have been used here. For example, as suggested in the discussion of the LPR method, a trend in the ratio over time might have been extrapolated over the future time period, and the estimate of the ratio so calculated substitued into equation (9). This approach was rejected, however, because three data points (1966, 1971 and 1976) are considered an insufficient base for such manipulations.

A second approach would have been to average the ratio over the three observations. This was done by Spaulding and Heady (1977) when estimating future urban land needs in the United States. Since the variation in the ratios was not great for this set of urban centres (Smit and Cocklin, 1981a), estimates so obtained would have been similar to those derived from any of the three ratios. Thus, the ratio reflecting the most recent relationship (1976) between total urban area and total urban population was selected.

Four population projections were prepared for each centre. These were derived by employing each of the two alternative assumptions with respect to the relationship between provincial population growth rate and individual urban centre growth rates discussed above in association with two estimates for the 2001 Ontario population (11.9 million and 10.1 million). These projections were substituted into equation (8) to yield the estimates of future land conversions presented in Table 2.

The estimated increase in the aggregate area of these 30 urban centers ranges from 64,315 hectares (Estimate 2) to 130,253 hectares (Estimate 3), equivalent to increases of 23 and 46 percent, respectively, over the total area occupied by this group of urban centres in 1976. The contribution of the largest urban centres to this total is substantial. The Toronto urban area accounts for more than 30 percent of the total expansion under any of the four estimates, and the estimated expansion of the 7 largest centres (those with a 1976 population of 200,000 or more) accounts for approximately 70 percent of the total. It is interesting to note that the two total estimates of future urban expansion based on a provincial population of 11.9 million are very similar, as are the two based on a provincial population of 10.1 million. There is considerably more variation among the estimates at the level of individual urban centre, however. This suggests that where the method will be used to examine implications of land conversions associated with the expansion of specific urban centres, perhaps in specialty crop growing regions, it may be appropriate to investigate more closely the recent trends in individual centre growth rates relative to provincial population growth trends.

4. IMPLICATIONS OF LAND CONVERSIONS

A discussion of the implications of future rural-urban land conversions must address implications for agriculture, since the hinterlands of Canadian cities tend to be devoted predominantly to agricultural uses. Evidence for this is provided by recent land conversion studies in which it was estimated that over

Table 2

LAND CONVERSION ESTIMATES FOR ONTARIO

URBAN CENTRES, 1976-2001

Urban Centre	Land Conversion Estimate			
	Ont. Growth Rate		Indiv. City Growth Rates	
	High Pop. 1 (ha)	Low Pop. 2 (ha)	High Pop. 3 (ha)	Low Pop. 4 (ha)
Barrie	1,606	821	2,807	1,843
Belleville	907	464	632	230
Brantford	2,256	1,154	1,767	738
Brockville	704	360	539	220
Chatham	957	490	973	503
Cornwall	1,016	520	515	93
Fort Erie	1,569	802	1,269	548
Guelph	1,560	798	2,105	1,261
Halton Hills	691	354	1,161	753
Hamilton	8,181	4,183	7,960	3,995
Kingston	2,631	1,345	1,993	803
Kitchener	5,259	2,689	8,883	5,771
London	4,850	2,480	5,540	3,067
Midland	1,060	542	977	471
North Bay	1,795	918	1,706	842
Oshawa	3,673	1,878	4,910	2,929
Ottawa	11,959	6,115	11,549	5,766
Peterborough	2,260	1,156	1,483	495
Sarnia	2,728	1,395	1,746	560
St. Catharines-Niagara	8,632	4,414	6,751	2,815
St. Thomas	1,082	553	1,065	539
Sault Ste. Marie	2,446	1,251	1,752	660
Stratford	765	391	607	257
Sudbury	4,476	2,289	6,125	3,691
Thunder Bay	3,192	1,632	2,132	730
Timmins	791	405	651	285
Toronto	40,416	20,716	47,184	26,386
Trenton	973	497	920	452
Windsor	5,842	2,987	3,431	938
Woodstock	1,399	716	1,120	478
Total	125,776	64,315	130,253	68,119
Percentage of total 1976 area	44	23	46	24

the two periods 1966-1971 and 1971-1976, 54 and 59 percent, respectively, of all rural land converted to urban uses was formerly devoted to improved agricultural land uses (Gierman, 1977; Warren and Rump, 1981). Additionally, over the same two periods 22 and 17 percent of the total rural land converted was previously devoted to unimproved pasture, indicating that over 75 percent of all rural land converted to urban land uses in these two time periods was concerned with farming. Approximately 60 percent of all rural land converted to urban uses over these two periods was in CLI capability classes 1-3.

Similarly, in Ontario 63 and 69 percent of all rural land converted to urban uses over the periods 1966-1971 and 1971-1976, respectively was previously devoted to improved agricultural uses. Accounting for the conversion of unimproved pasture, more than 80 percent of all rural land converted to urban uses over these two periods in that province was concerned with farm uses. Almost 80 percent of the rural land converted to urban uses over the two time periods in Ontario was in agricultural capability classes 1-3.

The expansion of urban centres has been found to adversely affect agriculture in many ways. The most obvious impact is a reduction in the amount of land available for agriculture. Many related impacts have also been identified, though. These include the idling of farmland at the peripheries of cities (Wibberley, 1959; Clawson, 1962; Hind-Smith and Gertler, 1962; Milnes and Reeds, 1979), increased land prices (Rodd, 1976b), decreased agricultural investment (Sinclair, 1967), farm fragmentation (Rodd, 1976b), and trespass and vandalism (Rawson, 1976). The method described in the following section of this report focusses on the land base implication; that is the actual reduction in the amount of land available for agricultural uses.

There is an important quality element associated with land that is converted. The coincidence of urban centres and high capability agricultural land has been discussed earlier in this report. In assessing the land base implications of either past or future conversions, it is necessary to identify the extent to which land that is well suited to agricultural activities is, or will be, converted to urban land uses and the implications of this in terms of the total agricultural land resource.

Of the total rural land converted to urban uses over the periods 1966-1971 and 1971-1976, that which had not formerly been devoted to agriculture was largely accounted for by forest uses. Over the period 1966-1971 almost 22 percent (18,811 hectares) of rural land in Canada converted to urban uses had previously been in forestry, 14 percent (12,423 hectares) of which was productive forests; for the period 1971-1976, 23 percent (14,700 hectares) of all rural land converted was in forestry, of which 18 percent (11,403 hectares) was productive. It is expected, though, that in view of the extremely large area of land devoted to forest uses across Canada, conversions associated with direct urban expansion would have little impact on the industry at a provincial or national level. In some areas specific species may be threatened to a relatively greater extent. For example, the hardwood forests of southern Ontario are threatened by urbanization and the quest for new agricultural lands.

Other rural land uses converted to urban uses over the two time periods represented

only very small proportions of the total land converted. This is not to say, though, that the encroachment of urban activities onto land previously devoted to these uses is not of importance. For instance, the development of land for urban land uses previously used for extractive purposes may create shortages of building materials such as sand and gravel. Outdoor recreation areas and important wildlife habitats might also be affected.

5. A METHOD TO ASSESS IMPLICATIONS OF FUTURE CONVERSIONS

The second analytical objective of this report is to develop a method by which the implications of future urban expansion for the agricultural land base can be assessed. One approach is to assess the implications of future land conversions in terms of the capability of the land to support particular land uses. This requires that assumptions be made regarding the pattern of future urban development. Since this is influenced by a variety of social, economic and political factors, which cannot be forecast with any accuracy, it becomes very difficult to make accurate predictions with respect to the future pattern of urban growth.

Instead, the land resource around the entire periphery of an urban centre can be examined. In the Ontario pilot study, maps of the urban centres prepared at a scale of 1:50,000, that are consistent with the data on which the land conversion estimates are based, were supplied by the Lands Directorate of Environment Canada. Around each centre a zone was drawn on the basis of two major definitional considerations:

1. the size of the zones are standardized in terms of the urban expansion estimates;
2. the zones resemble the general outline of the built-up area of an urban centre in the base year.

It was decided that the zones be approximately double the area of the largest of the four land conversion estimates for each centre, reflecting the fact that the exact location of future development within a zone is not known. At the same time, it seems unlikely that future development would occur to any great extent beyond an area of this size.

A boundary was sketched around each centre that was similar in form to the urban centre in the base year. The area within the boundary, not devoted to built-up uses, was calculated using a grid measuring procedure. After the initial attempt, adjustments were made until the area within the boundary was equal to approximately double the largest land conversion estimate (maximum difference of 10 percent). The area so defined is referred to hereafter as an Urban Expansion Zone (UEZ). The example of Chatham is used to illustrate the UEZ concept (Figure 3).

Political boundaries, provincial or international, are assumed to restrict the direction of future urban growth. Similarly, it was assumed that urban growth would not extend into provincial or national parks, nor into Indian Reserves. Certain physical factors, such as very steep topography and water bodies are also assumed to restrict the pattern of future urban development.

Although limitations defined by CLI agricultural capability sub-classes have been used to identify areas unsuitable for urban development (Neimanis, 1979; Gierman, 1979; Neimanis and McKechnie, 1980), the incidence

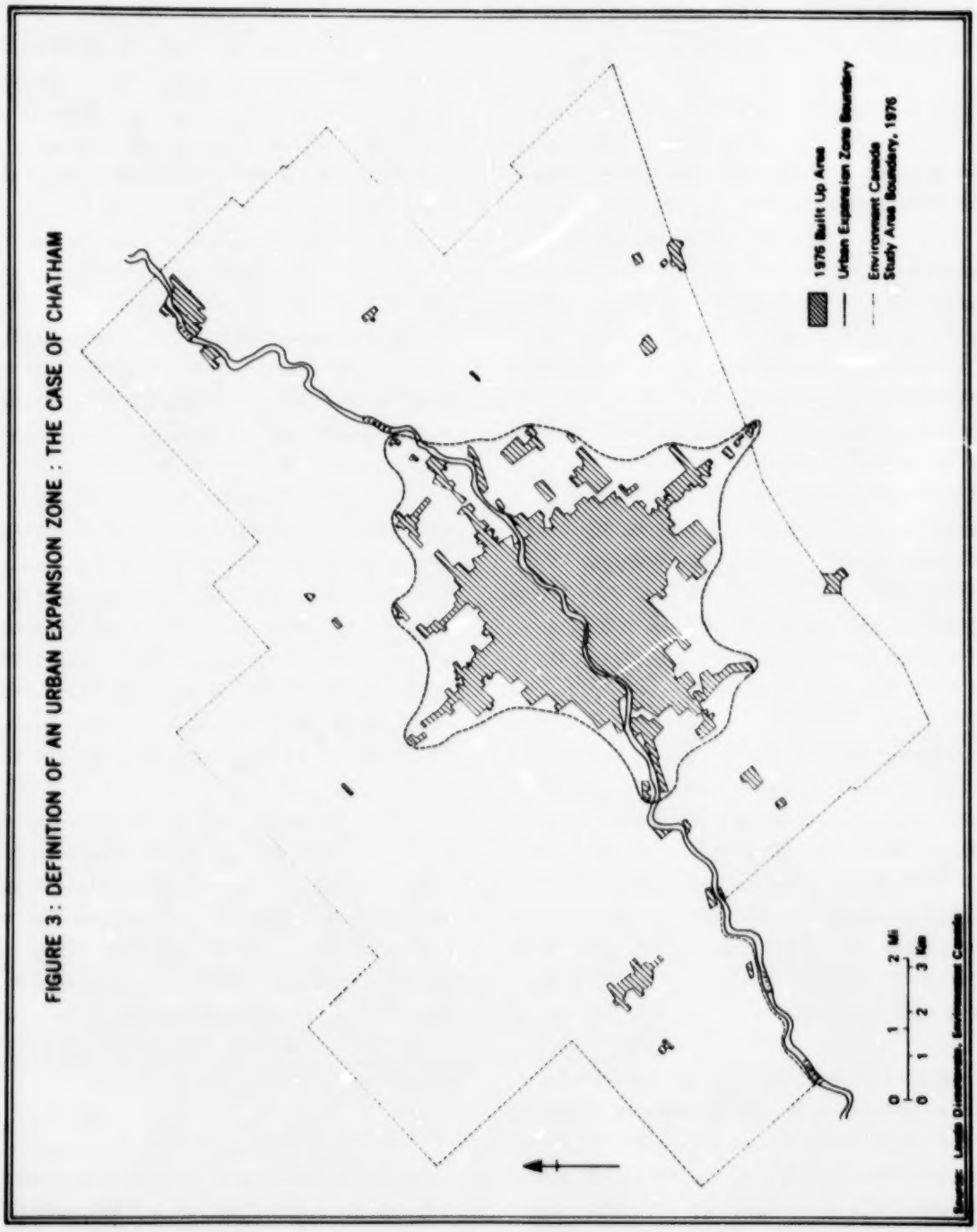


FIGURE 3 : DEFINITION OF AN URBAN EXPANSION ZONE : THE CASE OF CHATHAM

of urban development on such land (observed by overlaying maps of built-up areas and land capability) is considered sufficient reason to justify their retention in this study.

The method employed is somewhat subjective. However, the adoption of a more rigorous approach to defining these zones, such as perhaps the placement of the UEZ boundary at a uniform distance from the 1976 periphery, would have been impossible given the very irregular configurations of the built-up areas. Furthermore, although it might be argued that different individuals would place the boundary differently, given the above description of the method used, any differences would probably be minimal. Moreover, in view of the relative uniformity for the distribution of the agricultural capability classes in close proximity to the Ontario urban centres, it is unlikely that such changes that could be accommodated within the guidelines would drastically alter the measured distributions, at least in this particular case.

Having defined the UEZ, it is necessary to determine the distribution of its CLI capability classes for the particular rural land use under consideration. This might be done by a sampling method and the use of points, traverses or quadrates as the unit of observation (Berry and Baker, 1968). Associated with these methods are problems of sampling accuracy.

A more time consuming, but more comprehensive method is to take a complete inventory of the capability classes within a UEZ. Adopting this method, maps of the expansion zones were over-laid on 1:50,000 agricultural land capability maps and the distribution of land capability classes calculated using an area measuring grid.

The next task is to allocate the estimated urban expansion amongst the capability classes of the respective UEZs. Several different assumptions might be employed here. For instance, it has been suggested that urban development has a preference for land classified as having a high capability for agriculture, since land characteristics well suited for agricultural use are also well suited for urban development (Wibberley, 1959; Williams, 1955; Ciriacy-Wantrup, 1964; Neimanis, 1979). In view of this, the estimates of urban expansion might be concentrated on higher capability agricultural lands within the UEZs. Alternatively, as noted in the Introduction to this report, some provincial governments have attempted to preserve high capability agricultural land and advocate that urban development be directed, where possible, onto lower capability land. In the presence of such land use controls, the distribution of future urban development within the UEZs might be biased in favour of lower capability agricultural land.

When there is uncertainty regarding the actual location of future location with respect to agricultural land capability classes, though, an alternative is to assume that urban expansion will occur on CLI land classes for a specific land use in the same proportions as the classes are distributed within the UEZs. It is this assumption that is employed in the pilot study for Ontario.

In the following section the results of an analysis undertaken to assess the implications for agriculture of the estimated Ontario rural to urban land conversions are presented.

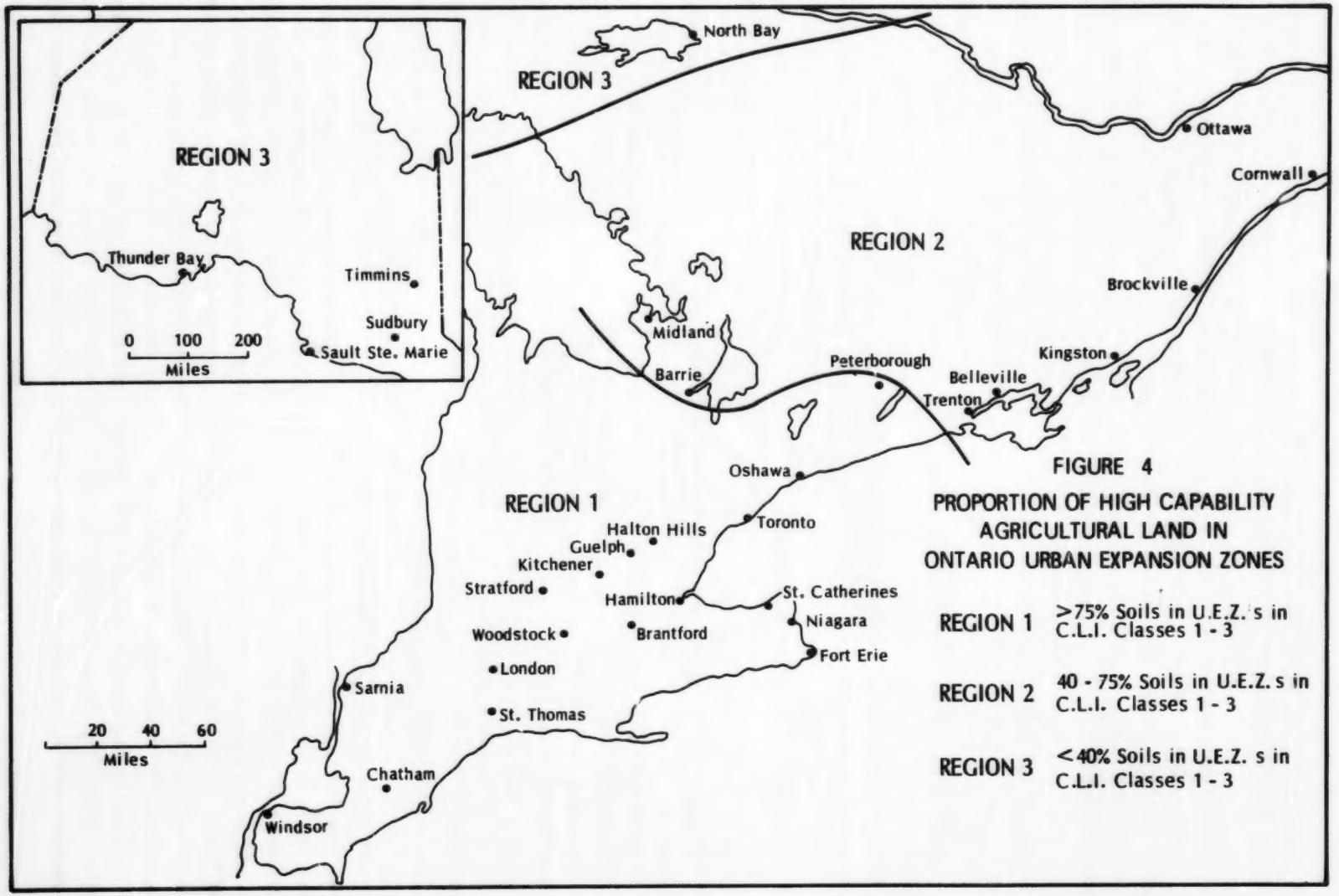


FIGURE 4

PROPORTION OF HIGH CAPABILITY AGRICULTURAL LAND IN ONTARIO URBAN EXPANSION ZONES

REGION 1	>75% Soils in U.E.Z.'s in C.L.I. Classes 1 - 3
REGION 2	40 - 75% Soils in U.E.Z. s in C.L.I. Classes 1 - 3
REGION 3	<40% Soils in U.E.Z. s in C.L.I. Classes 1 - 3

5.1 Implications of Future Land Conversions for the Ontario Agricultural Land Base

5.1.1 Land Conversions by CLI Class

Urban expansion zones were defined for each of the 30 Ontario urban centres and the distribution of their respective CLI agricultural land capability classes measured in the manner described above. The percentage distribution of the land classes for each UEZ is reported in Table 3.

It is evident that there is considerable variation among the urban centres in the proportions of the different capability classes in proximity to these cities. If the centres are grouped spatially, though, similarities in the proportional distributions among centres do emerge. This is illustrated in Figure 4 in which the province is divided into 3 areas: (1) south western, (2) south central and south eastern, and (3) nothern Ontario. In region 1, 75 percent or more of the UEZ land is of CLI classes 1-3 (the exception is Kitchener with 65 percent). The UEZs of Region 2 have between 40 and 75 percent of land in classes 1-3, the exceptions being Brockville (29 percent) and Cornwall (83 percent). In northern Ontario less than 40 percent of the UEZs is land in the higher capability classes.

The total conversion estimates for each urban centre were disaggregated by land capability class on the assumption that urban development will occur on the land classes in the same proportions as these classes are distributed within the UEZs. The results for Land Conversion Estimate 2 (Ontario population growth rate, low population) are presented in map form in Figure 5. It is apparent that the greatest extent of land conversion will occur in southern Ontario, especially along the western shore of Lake Ontario. Furthermore, urban expansion in the southern part of the province is estimated to occur predominantly on higher capability agricultural land. Mapping any of the other conversion estimates would have produced a similar pattern, although the areas of the circles would have differed.

Aggregating these values by land capability class over all 30 urban centres resulted in the values of Table 4. Under the assumptions employed here, it is estimated that between 48,930 hectares (Estimate 2: Ontario growth rate, low population) and 99,420 hectares (Estimate 3: Individual city growth rates, high population) of class 1-3 land, the land generally accepted as being the best suited for agriculture, will be converted to urban land uses over the period 1976-2001. This represents approximately 76 percent of the total estimated conversion. Of this, approximately 40 percent is class 1 land.

These estimates, although large, are not necessarily cause for concern. One method of assessing the significance of the estimated conversions for the agricultural land base is to express the conversion estimates as a proportion of the total land in the province of each capability class.

Information was obtained on the provincial distribution of land by CLI class from the Canada Land Data System (CLDS) which provides a cross-tabulation of agricultural land capability and 1965 land use (Environment Canada, 1976). Since the concern here is with land that may be converted to urban uses, the areas designated by the CLDS as being devoted to urban uses of each capability class, updated to 1976 using data from Gierman (1977)

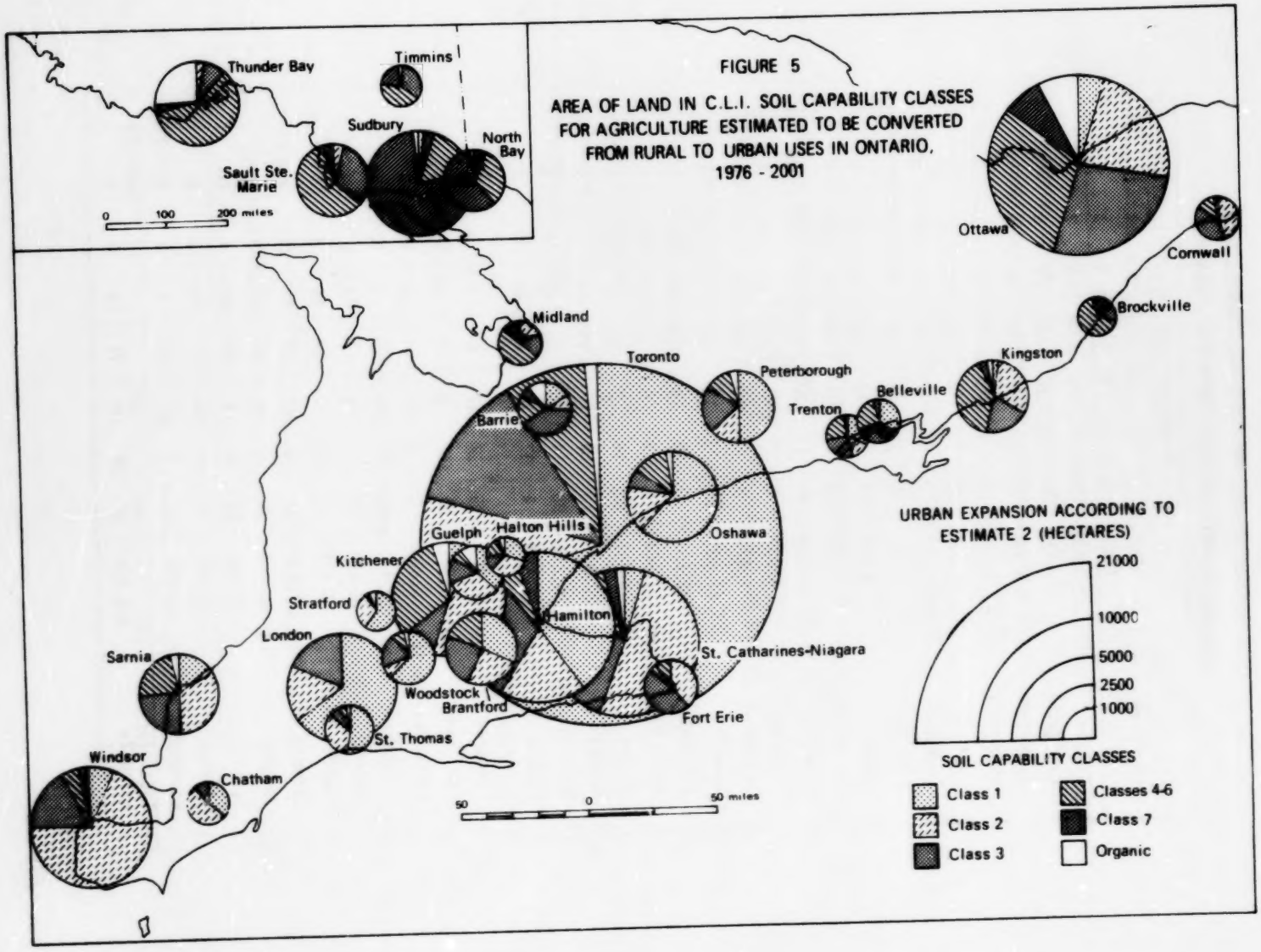


FIGURE 5
AREA OF LAND IN C.L.I. SOIL CAPABILITY CLASSES FOR AGRICULTURE ESTIMATED TO BE CONVERTED FROM RURAL TO URBAN USES IN ONTARIO, 1976 - 2001
Thunder Bay
Timmins
Sudbury
North Bay
Sault Ste. Marie
0 100 200 miles
Ottawa
Cornwall
Brockville
Kingston
Midland
Toronto
Peterborough
Belleville
Trenton
Barrie
Oshawa
Guelph
Halton Hills
Kitchener
Stratford
Hamilton
London
St. Catharines-Niagara
Sarnia
Woodstock
Brantford
Fort Erie
St. Thomas
Windsor
Chatham
50 0 50 miles
URBAN EXPANSION ACCORDING TO ESTIMATE 2 (HECTARES)
21000
10000
5000
2500
1000
SOIL CAPABILITY CLASSES
Class 1
Class 2
Class 3
Classes 4-6
Class 7
Organic

Table 3

DISTRIBUTION OF CLI AGRICULTURAL CAPABILITY CLASSES IN ONTARIO URBAN EXPANSION ZONES

Urban Centre	UEZ Area (ha)	Agricultural Capability Class						
		1 %	2 %	3 %	1-3 %	4-6 %	7 %	Org. %
Barrie	5,337	16	9	42	67	16	7	10
Belleville	1,789	34	5	30	69	26	5	0
Brantford	4,151	32	25	23	80	20	0	0
Brockville	1,382	5	2	22	29	67	3	1
Chatham	1,838	37	53	10	100	0	0	0
Cornwall	2,013	0	46	37	83	15	0	2
Fort Erie	2,881	0	20	66	86	14	0	0
Guelph	4,526	37	34	15	68	6	0	8
Halton Hills	2,388	32	33	14	79	14	4	3
Hamilton	17,556	40	19	30	89	6	5	0
Kingston	4,937	2	31	21	54	40	3	3
Kitchener	18,470	8	48	9	65	30	C	5
London	11,981	65	17	18	100	0	0	0
Midland	2,201	0	21	18	39	46	13	2
North Bay	3,963	0	1	4	5	36	58	1
Oshawa	9,657	63	16	7	86	12	0	2
Ottawa	22,931	5	23	27	55	31	7	7
Peterborough	4,296	50	14	20	84	13	0	3
Sarnia	5,482	14	37	24	75	22	0	3
St. Catharines-Niagara	18,307	5	52	31	88	8	3	1
St. Thomas	2,331	53	36	8	97	2	0	1
Sault Ste. Marie	4,800	0	5	31	36	60	4	0
Stratford	1,431	60	32	3	95	0	0	5
Sudbury	12,088	0	2	3	5	17	77	1
Thunder Bay	6,475	0	3	9	12	59	2	27
Timmins	1,600	0	0	37	37	41	20	2
Toronto	94,719	71	9	12	92	7	0	1
Trenton	1,995	32	16	24	72	24	4	0
Windsor	12,350	6	70	16	92	5	3	0
Woodstock	3,039	64	7	21	92	6	0	2
Total for all UEZs	286,914	37	22	18	77	15	6	2

Table 4
AGRICULTURAL CAPABILITY OF LAND ESTIMATED TO BE CONVERTED FROM RURAL TO URBAN USES IN ONTARIO, 1976-2001

CLI Agricultural Capability	Land Conversion Estimate			
	Ont. Growth Rate		Indiv. City Growth Rates	
	High Pop. 1	Low Pop. 2	High Pop. 3	Low Pop. 4
Class 1 (ha)	45,584	23,308	50,942	27,858
Percent of Total	36	36	36	36
Class 2 (ha)	26,856	13,734	25,933	12,945
Percent of Total	21	21	20	19
Class 3 (ha)	23,252	11,888	22,545	11,290
Percent of Total	19	19	17	17
Total in Classes 1-3 (ha)	95,692	48,930	99,420	52,093
Percent of Total	76	76	76	77
Classes 4-6 (ha)	19,871	10,159	19,563	9,901
Percent of Total	16	16	15	15
Class 7 (ha)	6,948	3,554	7,975	4,428
Percent of Total	6	6	6	7
Organic (ha)	3,266	1,671	3,296	1,697
Percent of Total	3	3	3	3
Total	125,776	64,315	130,253	68,119
Percent	100	100	100	100

and Warren and Rump (1981), were subtracted from the area of land in each capability class.

The conversion estimates were then expressed as a percentage of these provincial totals for each capability class (Table 5). The greatest proportional conversion is of class 1 land, and as agricultural capability decreases, so does the percentage converted. This suggests that higher capability land is over-represented within the UEZs in relation to its distribution throughout the province - a finding consistent with that of Manning and McCuaig (1977) and Neimanis (1979).

The estimated percentage conversion of class 1 land ranges from 1.1 percent (Estimate 2) to 2.4 percent (Estimate 3) and for 1-3 from 0.8 percent to 1.5 percent.

Table 5
ESTIMATED LAND CONVERSIONS AS A PERCENT OF TOTAL LAND IN ONTARIO BY AGRICULTURAL CAPABILITY CLASS

CLI Class	Land Conversion Estimate			
	Ont. Growth Rate		Indiv. City Growth Rates	
	High Pop.	Low Pop.	High Pop.	Low Pop.
	1 %	2 %	3 %	4 %
1	2.2	1.1	2.4	1.3
2	1.3	0.7	1.2	0.6
3	1.0	0.5	1.0	0.5
1-3	1.5	0.8	1.5	0.8
4-6	0.5	0.3	0.5	0.3
7	0.1	0.1	0.1	0.1
Organic	0.2	0.1	0.2	0.1

5.1.2 The Effect of Climate

The suitability of an area for agriculture depends not only on soil characteristics but also upon climate. Climate affects agriculture through the influence of heat and moisture on the kinds of crops that can be grown without major environmental modifications. It is treated in the CLI as a sub-class and is used to indicate an adverse departure from what is considered the median climate of a region (Environment Canada, 1972). This treatment is not entirely satisfactory, though, for establishing the climatic suitability of a region for agriculture.

Soils are placed in the climate sub-class only if there are no soil-based limitations for agriculture. Also, the nature of the limitation is not indicated. The median climate is established at the sub-regional or local level and, thus, the limitation is location specific. Furthermore, it has been suggested that basing the limitation on a median climate does not allow for the variation in climate from one season to another or for the interaction of climate with soil type (Miller and Brown, 1980).

A useful index by which the climatic suitability of a region can be rated for plant growth is the Corn Heat Unit (CHU), a cumulative measure of temperature which indicates the amount of heat available over the growing season for corn (Chapman and Brown, 1966). In Ontario, CHU range from 3,700 in the south of the province to less than 2,100 in northern regions (Figure 6).

Crops have different temperature requirements and it is possible to express these in terms of CHU. Tobacco, for example, requires greater than 2,900 CHU while soybeans require greater than 2,600 CHU for satisfactory yields (Tosine, 1978).

Crops also have particular requirements with respect to soils and in combining these with temperature requirements, the acreages suitable for the production of specific crops can be determined. Tosine (1978) does this for grain corn on the assumption that this crop requires land in capability classes 1-3 and 2,500 CHU or more.

From Figure 6 the urban centres in regions of 2,500 CHU or more were identified and the estimated conversion of class 1-3 land associated with the expansion of these centres was calculated. Expressing these values as a percentage of the total area defined by Tosine as being suitable for grain corn indicates the proportion of the land resource for this crop that may be affected by future land conversions (Table 6).

The percentage values of Table 6 are higher than the corresponding values of Table 5, indicating that a greater proportion of the total provincial class 1-3 land is in regions of less than 2,500 CHU than the proportion of land in these classes and regions of less than 2,500 CHU that is estimated to be converted to direct urban land uses.

It is expected that, in general, a crop with lower CHU requirements would result in lower percentage values relative to those of Table 6, while a crop demanding greater than 2,500 CHU would produce higher corresponding values. This would be attributable to the fact that higher CHU ratings occur in southern regions of the province and this is also where the greatest extent of urban expansion is expected.

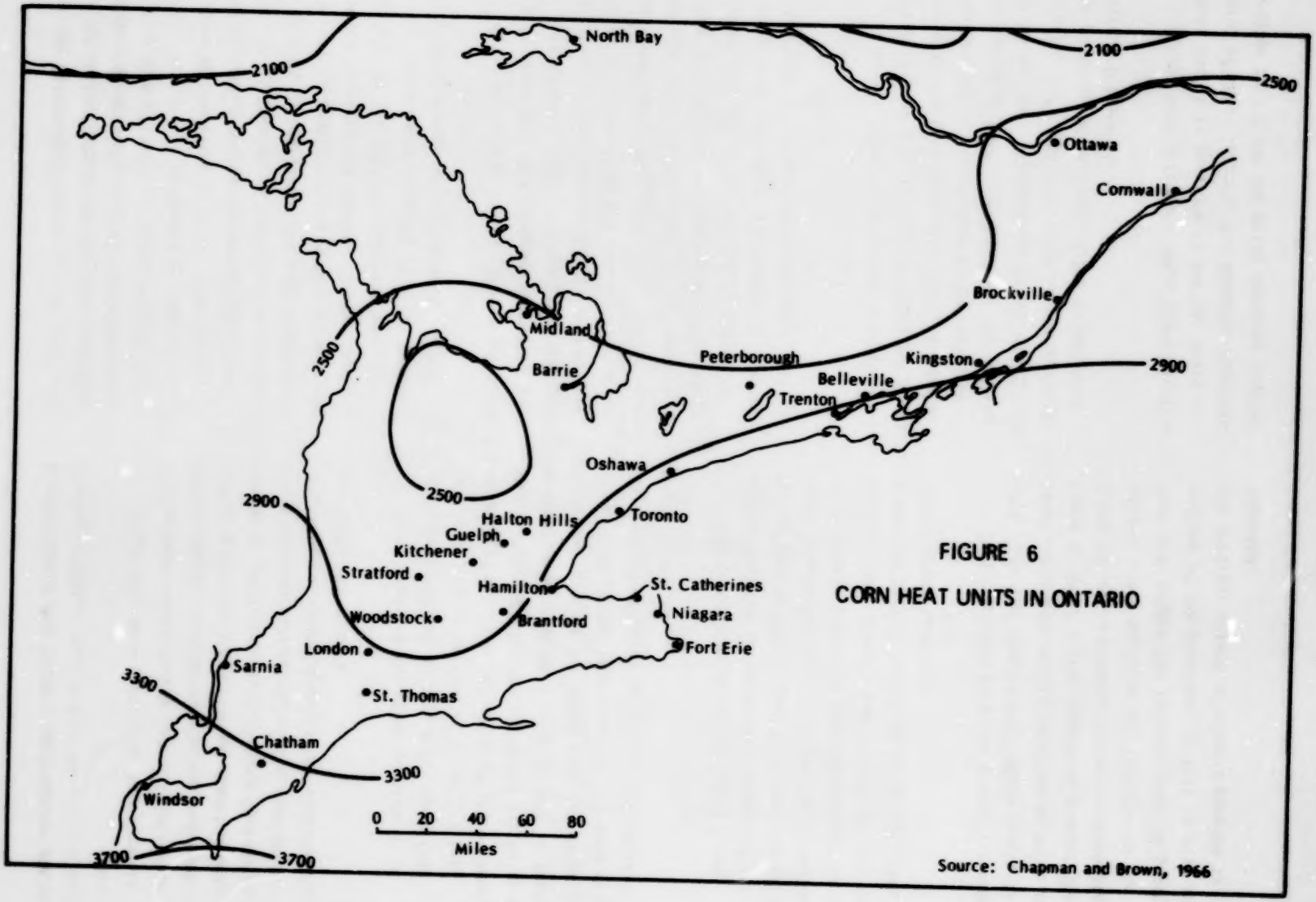


FIGURE 6

CORN HEAT UNITS IN ONTARIO

Source: Chapman and Brown, 1966

Table 6
PERCENTAGE OF LAND SUITABLE FOR
GROWING GRAIN CORN IN ONTARIO ESTIMATED TO BE
CONVERTED TO URBAN LAND USES, 1976-2001

CLI Class	Land Conversion Estimate			
	Ont. Growth Rate		Indiv. City Growth Rates	
	High Pop.	Low Pop.	High Pop.	Low Pop.
	1	2	3	4
	%	%	%	%
1	2.8	1.4	3.1	1.7
2	1.5	0.8	1.5	0.7
3	2.0	1.0	2.0	1.0
1-3	2.1	1.1	2.2	1.2

5.1.3 Agricultural Performance Indices

The assessment of the implications of future urban expansion on agriculture, expressed in terms of the loss of various capability classes, presents some difficulties in interpretation since, although it is known that class 7 soils are inferior to class 1, the overall impact on the land base is not readily apparent because the CLI ranks but does not quantify the differences between classes. An alternative perspective is provided by deriving a summary value that incorporates the differences between the capability classes. This can be done using agricultural performance indices.

Both Anderson (1971) and Hoffman (1971) derived such indices on the basis of crop yields. Anderson found that mean yields of birdsfoot trefoil declined consistently with decreasing land quality. Yields on class I land were attributed a value of 1.00 and index values for the lower classes were derived by expressing their mean yields as a fraction of the mean yield on class 1 land (Column 1, Table 7).

Hoffman, working with grain corn, barley, and oats, also found yields to decline with decreasing land capability and developed an index series for each of the crops. Although

Table 7
AGRICULTURAL PERFORMANCE INDICES

CLI Class	Index Based on:	
	Birdsfoot Trefoil*	Common Field Crops**
1	1.00	1.00
2	0.80	0.80
3	0.66	0.64
4	0.58	0.49
5	0.49	No value
6	0.49	No value
7	No value	No value

Source: *Anderson, 1971
**Hoffman, 1971

there were some differences in the indices over the three crops, Hoffman developed a single index series applicable to all three (Column 2, Table 7). Indices could not be calculated for classes 5-7 as information on yields for these classes could not be obtained. Hoffman noted that these crops are seldom grown on lower capability land.

The estimates of future land conversions, expressed by land capability class, are converted to class 1 equivalents by multiplying the areas of each land class estimated to be converted by the appropriate performance index value. For classes 1-4, Hoffman's index series for common field crops is used; Anderson's series is used for classes 5 and 6. The land areas are thus converted to a common unit (Class 1 equivalents) and can be summed. This procedure reduces the estimates, previously expressed according to individual land class, to a single summary value.

The Canada Land Data System information on the distribution of land by land class is similarly expressed to give a total of 7,242,894 hectares of class 1 equivalent land in Ontario. Each of the conversion estimates, as class 1 equivalents, was expressed as a percentage of the Ontario total (Table 8). The percentage values range from 0.7 (Estimates 2 and 4) to 1.3 (Estimates 1 and 3) and support the previous findings: The estimated land conversions do not represent a substantial proportion of the total agricultural land resource.

Table 8
AREA OF CLASS 1 EQUIVALENT LAND
ESTIMATED TO BE CONVERTED TO URBAN USES, 1976-2001 AND
AREA ESTIMATED TO BE CONVERTED AS A PERCENTAGE OF
ONTARIO CLASS 1 EQUIVALENT LAND.

	Land Conversion Estimate			
CLI Class 1	Ont. Growth Rate		Indiv. City Growth Rates	
	High Pop.	Low Pop.	High Pop.	Low Pop.
	1	2	3	4
Area of Class 1 Equivalent Land (ha)	91,867	46,831	95,703	50,292
Percent of Ontario Class 1 Equivalent Land	1.3	0.7	1.3	0.7

5.2 The Need for Further Assessments

The discussion above has illustrated an approach to assesssing the implications for the agricultural land base of future rural to urban land conversions. This, by no means, represents a comprehensive assessment of the impact of future urban development on agriculture.

Analyses might be undertaken to assess the impact on crops that have very specific soil and climatic requirements. The results of the above analysis suggest that the impact of the estimated conversions on land for general agriculture will be relatively minor. However, the commercial production of specialty crops, such as fruits and vegetables, is greatly restricted by soil and climate conditions, and in Canada those areas capable of producing these crops tend to be within the vicinity of major urban centres. Thus, the impact of future urban development on these crops may be greater.

The method described above estimates the land base implications only in terms of actual acreage to be converted. The impact of future land conversions might also be effectively evaluated in terms of the loss in productive capacity and the consequent effects on local food supply levels and for trade. This requires information on agricultural yields of the land estimated to be converted to urban uses.

There is clearly a need to assess the implications of land use changes relative to the demands for the products from land use activities. As Dumanski et al. (1972) note, while interpretation of soil surveys provide evaluations of performance, a variety of economic, social and political factors, as

well as land characteristics, must be considered in determining efficient land use patterns. Thus, as Smit (1981) suggests, it is necessary to consider the demands for products and services from various land uses, together with the supply of land if the broad implications of possible land use trends are to be evaluated in a systematic manner.

Furthermore, this analysis has examined only approaches to assessing the land base implications of future land conversions for agriculture. Attempts should also be made to develop methods to evaluate the significance of other impacts, such as on land prices, farm investment levels, extent of farm fragmentation, and so on.

It should be emphasised that the analysis considers only the conversion of rural land as a result of direct urban expansion. Considerable evidence exists to show that substantial areas of land at the peripheries of urban centres lie idle prior to urban development (Wibberley, 1959; Clawson, 1962; Hind-Smith and Gertler, 1962; Milnes and Reeds, 1979). Hind-Smith and Gertler (1962) suggest that the area of land idled may account for more than double the area actually developed for urban uses.

Also, scattered urban land uses such as rural residential development and urban induced infrastructures such as highways and transmission lines have impacts on agricultural land. Apart from the actual removal of land from traditional agricultural uses, this type of development has been found to adversely affect agriculture through farm fragmentation, increased taxations for farmers, adoption of nuisance laws, trespass and vandalism, and increased land prices (Rodd, 1976b; Brown, 1977; Bryant and Russwurm, 1979).

Additionally, land with a high capability for agriculture may also be converted to rural land uses other than agriculture, such as forestry, recreation, aggregate extraction, and so forth. Thus, while the analyses described here suggest that direct rural to urban land conversions on high capability land will be limited, the total area of land well suited to agricultural activities that is converted to uses other than agriculture in the future will be considerably greater. In order to identify the 'total impact' of future land conversions on the agricultural land resource demands, therefore, that the conversion of rural land to all uses other than agriculture also be estimated.

The current Urban Centred Region project of the Canada Land Use Monitoring Program of Lands Directorate is responding to many of these needs. It will be possible, for example, to obtain data on idle land and all types of land use conversion within urban centred regions using a land activity/cover classification devised for monitoring purposes.

6. FEASIBILITY OF A NATIONAL STUDY

The objectives of this research are to develop a method by which estimates of future rural to urban land conversions can be estimated and to develop an approach to assessing implications of those conversions for the agricultural land resource. A similar study conducted at the national level would provide useful information on the extent to which future urban expansion will affect the agricultural land base in other provinces and for the nation as a whole. Also, the impact of future urban development on other rural land uses could be investigated.

The analytical procedure in undertaking a national level study would be essentially the same as that described and adopted here for the Ontario pilot study. Land-Population Ratios for each urban centre can be calculated from the urban area and urban population data presented in the land conversion studies of the Lands Directorate (Gierman, 1977; Warren and Rump, 1981). Population projections for individual urban centres would then be substituted into the estimating equation (equation 9) to derive the estimates of future land conversions.

Canada Land Inventory maps for the various rural land uses at a scale of 1:50,000 are available for the areas surrounding many of the major urban centres in Canada. Where these are not available at that scale, maps prepared at a scale of 1:63,360 or at the larger scale of 1:250,000 could be changed photo-mechanically to the 1:50,000 scale, as done for the Lands Directorate land conversion studies (Gierman, 1977).

Urban expansion zones would then be defined according to the guidelines presented above and the distribuiton of rural land use capability classes measured. By employing assumptions concerning the distribution of future urban development across land capability classes, the conversion estimates can be dissected by capability class, permitting the comparison of conversion estimates relative to the total land resource base for a particular land use.

Thus, the implementation of a national level study of the type described above presents no major methodological problems. In extending this research, it would be useful to estimate the extent of indirect urban expansion, as well as direct expansion. Also, approaches to the assessment of implications of future land conversions could profitably be extended beyond what has been described here, both for agriculture and when considering land uses other than agriculture. Some suggestions for further evaluations of the possible impacts on agriculture are presented in the section above.

The greatest concern with rural to urban land conversions has been expressed over the impact on agriculture. A national level investigation should, therefore, assess the impact of future urban expansion on the national agricultural land resource. Analyses could be conducted both at the provincial level, as described here for Ontario, and at the national level. The former would permit identification of those provinces in which the impact on the agricultural land resource will be proportionately greatest, while the latter would provide a perspective on the possible implications for the national land resource.

It is suggested that subsequent analyses of the impact of urban development on the agricultural land base give greater consideration to the implications for specialty agricultural activities, such as vegetables and fruits. It is indicated earlier in this report that the land resource for specialty agricultural activities in Canada is very limited, and regions like the Okanagan Valley of British Columbia and the Niagara Fruit Belt of Ontario are coincident with major urban centres. Thus, although the impact on agricultural land generally may be modest, the impacts on land capable of supporting specialty crop production are likely to be of much greater significance.

Urban expansion occurs not only on land with a high capability for agriculture, but also on land with high capabilities for other rural land uses. The implications of future urban expansion for rural land uses other than agriculture might also be investigated.

For example, attention might be devoted to examining implications of future urban expansion for forest resources. Because the conversion of forest land to urban uses represents only a very small proportion of the total land devoted to forestry, it may be more appropriate that analyses focus on specific regions where conversion rates of forestry to urban uses are highest and forest resource regions that are limited in extent, such as the hardwood forest zone of southern Ontario, rather than examining the impact on forestry generally.

The favourable economic conditions being experienced in some western provinces has led to the rapid expansion of urban centres. Calgary and Edmonton in Alberta are notable examples. The possible impacts of continued high rates of development on land resources would greatly assist effective land use planning in these areas. Thus, particular attention might be devoted to estimating future land conversions in areas of rapid urban growth.

There is considerable scope for evaluating alternative assumptions at various stages of the analysis. For example, alternative assumptions with respect to density of development might be considered. This can readily be incorporated by adjusting the Land-Population Ratios. There is also opportunity to consider alternative methods and assumptions in projecting urban centre populations.

Two alternatives are suggested above relating to the distribution of urban development across agricultural land capability classes. An assessment of these two alternatives resulted in substantial differences in the estimates of the area of land of higher capability agricultural land converted in Ontario (Smit and Cocklin, 1981b). This suggests that there is value in assessing alternatives with respect to the distribution of future urban development across land capability classes.

Estimation of future rural to urban land conversions at a national scale and consideration of the implications of these conversions for selected rural land uses would represent a worthwhile contribution to the study of land use in Canada. Such information would provide the opportunity to identify regions where future land conversions may have a substantial impact on land resources and to foresee consequent problems that may arise with respect to meeting the requirements from various land use activities. This would facilitate the effective management of the land resource, a primary concern of both the federal and provincial governments.

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